In the Specification:

Page 1 before the first paragraph, has been amended to include the following insert:

CLAIM FOR PRIORITY

a 1

This application claims priority to International Application No. PCT/DE00/00005 which was published in the German language on January 3, 2000.

Page 1 before the first paragraph, please delete the following:

~~Description~~

Page 1, between lines 4 and 5 has been amended to include the following heading:

a 2 TECHNICAL FIELD OF THE INVENTION

Paragraph beginning on line 6 of page 1 has been amended as follows:

a 3

The invention relates to a method and a device for wireless data transmission, and in particular, to wireless data transmission where information about interference in a message transmission system is obtained in the receiver.

Page 1, between lines 10 and 11 has been amended to include the following heading:

a 4 BACKGROUND OF THE INVENTION

Paragraph beginning on line 11 of page 1 has been amended as follows:

a 5

In message or data transmission, it is desirable to obtain as uncorrupted a transmission of the user signals as possible, to suppress interference which exists at the same time and in the same frequency band in addition to the wanted signal, and thermal noise, as well as possible in the receivers. To be able to selectively take measures against interference, it is required to know as much as possible about the characteristics of the interference. Apart from the intensity of the

interference, such characteristics are, for example, its spectrum, its correlation properties and the directions of incidence of the interfering signals at the receiver.

Paragraph beginning on line 24 of page 1 has been amended as follows:

In many cases such as, for example, in permanently installed radio transmission links, potential interfering influences by other permanently installed transmitters, which do not emit any user signals from the point of view of the transmission link under consideration, are known. According to the prior art, such interfering influences can be suppressed by simple measures such as directional transmission and reception, a procedure normally used in microwave radio. In many cases, especially in the multi-subscriber systems of mobile communication, such information on the properties of the interference is not known. Accordingly, countermeasures adapted to the interference cannot be easily taken. Assuming interference-limited multi-subscriber systems in which, therefore, the interference is essentially caused by other users of one's own system, the time correlation of the interfering signals is equal to the time correlation of the wanted signals and is thus known as long as interfering signals which are incident from different directions are uncorrelated. Knowledge of the time correlation of the interfering signals can be utilized in the receiver for improving the transmission quality by decorrelating the interference.

Paragraph beginning on line 9 of page 2 has been amended as follows:

TD-CDMA as disclosed in A. Klein, P.W. Baier: Linear unibiased data estimation in mobile radio systems applying CDMA. IEEE Journal on Selected Areas in Communications, Vol. 11, 1993, p. 1058 to 1066, as an example for third-generation mobile radio systems, uses the hybrid FDMA/TDMA/CDMA (frequency/time/code division multiple access) method. The time correlation of the interfering signals can be taken into consideration in the data detection. An example in which no information about the correlation properties of the interference are utilized is the WCDMA (wideband CDMA) disclosed in F. Adachi, K. Ohno, A. Higashi, T. Dohi, Y.

Okumura: Coherent multicode DS-CDMA mobile radio access DS-CDMA mobile radio system, IEICE Transactions on Communications, Vol. E79-B, No. 9, 1996, p. 1316 to 1324 and F. Adachi, M. Sawahashi: Wideband multi-rate DS-CDMA for next generation mobile communications systems. Proc. IEEE Wireless Communications Conference (WCC'97), Boulder, 1997, p. 57 to 62, air interface concept which is also proposed for third-generation mobile radio systems and which is based on the hybrid FDMA/CDMA multiple access method.

[Paragraph beginning on line 20 of page 2 has been amended as follows:]

The disadvantageous factor in the transmission methods corresponding to the prior art, is that they do not obtain information on the received interference (or only to a very limited extent). Hence, they do not use such information to a desirable degree for improving the transmission quality. For example, no directional information at all is obtained with respect to the interference. If multiple-antenna receivers are used, directional patterns could be generated. For example, when using array antennas, which selectively have less gain for those directions from which strong interfering signals arrive at the receiver, the ratio between useful power and interference power at the receiver end is maximized. However, this would require knowledge of the directions of interference which cannot be obtained in the systems according to the prior art.

[Paragraph beginning on line 1 of page 3 has been amended as follows:]

The system described above of the time correlations of the interference, for example in the case of TD-CDMA, are not about obtaining information about the interference. Rather, using knowledge about the interference is questionable, especially in mobile communication, since the instantaneous characteristics of the interference can greatly deviate from those assumed due to the permanent changing in time of the spatial constellation of the mobile stations which, as a rule, is not predictable.

The prerequisite of uncorrelated interference signals arriving at the receiver from different directions, which has been addressed above, is also not generally met. If the signal of an interference source propagates toward the receiver along a number of paths with different delay, and/or if the interfering signals coming from one interference source have different directions of incidence at the location of the receiver, the aggregate interference signal produced by superposition of the interference signals at the receiving location have different time correlations than the individual interference signals. Thus, they also have different time correlations from those of the user signal which have been assumed.

Page 3, between lines 25 and 26 has been amended to include the following heading:

SUMMARY OF THE INVENTION

In one embodiment of the invention, there is a method for the wireless data transmission using at least one transmitter and at least one receiver, the receiver having one or more receiving antenna. The method includes, for example, utilizing information on received interference signals to improve the quality of transmission of the data transmission, obtaining quantitative information about received user signals from the received signals of one of the antennas by using a first signal processing algorithm, and obtaining quantitative information about the received interference signals from the received signals of one of the antennas and the quantitative information obtained about the received user signals by using a second signal processing algorithm wherein the quantitative information about the received interference signals is used to generate a directional pattern at the transmitter.

In one aspect of the invention, the first signal processing algorithm provides an estimate of the transmitted user data.

In another aspect of the invention, the first signal processing algorithm provides an estimate of the characteristics of the radio channels operating between the transmitters and the receiver.

5

In still another aspect of the invention, the second signal processing algorithm includes algorithms to reconstruct the user signals received from the receiving antennas by the quantitative information obtained about the signals.

In yet another aspect of the invention, the second signal processing algorithm includes a weighted or unweighted subtraction of the reconstructed received user signals from the total received signals.

In another aspect of the invention, the second signal processing algorithm includes a forming of the spatial covariance matrix of the received interference signals.

In yet another aspect of the invention, the second signal processing algorithm includes a forming of the temporal covariance functions of the received interference signals at each of the antennas.

In still another aspect of the invention, the second signal processing algorithm includes a forming of the total covariance functions of the received interference signals.

In another aspect of the invention, the second signal processing algorithm includes an estimating of the spatial, temporal and/or total covariance functions by finite temporal averaging over the received interference signals.

In still another aspect of the invention, the second signal processing algorithm includes an estimating of the directions of incidence of the interference.

In yet another aspect of the invention, the second signal processing algorithm includes an estimating of the power and/or the spectral shape of the interference.

In another aspect of the invention, the first signal processing algorithm includes a forming of the spatial covariance matrix of the received user signals.

In yet another aspect of the invention, the first signal processing algorithm is based on the principle of a single user detection in the case of data transmission.

In another aspect of the invention, the first signal processing algorithm is based on a principle of multi-user detection in the case of data transmission.

In still another aspect of the invention, the first signal processing algorithm is based on a principle of a rake receiver in the case of data transmission.

In yet another aspect of the invention, the first signal processing algorithm includes forward error correction decoding at the receiver end during data transmission.

In still another aspect of the invention, the first signal processing algorithm is based on a principle of the zero-forcing algorithm.

In yet another aspect of the invention, the first signal processing algorithm is based on a principle of maximum-likelihood estimation or minimum mean square error estimation.

In one embodiment of the invention, there is a system for wireless data transmission. The system includes, for example, a receiver having one or more receiving antennas utilizing information on received interference signals to improve the quality of transmission of the data transmission, wherein quantitative information is obtained about received user signals from the received signals of one of the antennas by using a first signal processing algorithm, and the quantitative information about the received interference signals is obtained from the received signals of one of the antennas and the quantitative information obtained about the received user signals by using a second signal processing algorithm wherein the quantitative information about the received interference signals is used for generating a directional pattern at the transmitter; and a transmitter to generate a directional pattern based on the quantitative information about the received interference signals.

Page 3, between line 25 and line 26 has been amended to include the following:

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 illustrates an exemplary receiving system in the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Paragraph beginning on line 26 or page 3 has been amended as follows:

In one method of the invention, Ka receiving antennas are assumed. In this method, information on the user signal is first obtained from the received signals of the antennas. From the total received signals which contain both the user signal(s) and the interference signal(s), and the information, previously obtained about the user signal(s), information about the interference signal(s) can then be obtained.

[Paragraph beginning on line 1 of page 4 has been amended as follows:]

In one aspect of the invention, the information about the interference signals is obtained, for example, by an approximate reconstruction of the received user signals and by subsequent subtraction of the reconstructed user signals from the total of the received signals. This embodiment thus provides an estimate of the time functions $\underline{\hat{n}}^{(ka)}(t), ka = 1..Ka$ of the interference at the Ka receiving antennas.

Paragraph beginning on line 8 of page 5 has been amended as follows:

In another aspect of the invention, the estimates $\underline{\hat{n}}^{(ka)}(t)$ determined as above, the estimates

$$\underline{\hat{R}}_n^{(l.m)}(\tau) = E\left\{\underline{\hat{n}}^{(l)}(t)\cdot(t+\tau)\right\} \qquad l,m = 1..Ka \tag{1}$$

of the temporal covariance functions of the interference signals effective at the antennas can be obtained. In addition, the normalized spatial covariance matrix

$$\underline{\hat{R}}_s = \frac{1}{\sigma^2}\begin{pmatrix} E\left\{\underline{\hat{n}}^{(1)}(t)\cdot\underline{\hat{n}}^{(1)}*(t)\right\} & E\left\{\underline{\hat{n}}^{(1)}(t)\cdot\underline{\hat{n}}^{(Ka)}*(t)\right\} \\ E\left\{\underline{\hat{n}}^{(2)}(t)\cdot\underline{\hat{n}}^{(1)}*(t)\right\} & E\left\{\underline{\hat{n}}^{(2)}(t)\cdot\underline{\hat{n}}^{(Ka)}*(t)\right\} \\ E\left\{\underline{\hat{n}}^{(Ka)}(t)\cdot\underline{\hat{n}}^{(1)}*(t)\right\} & E\left\{\underline{\hat{n}}^{(Ka)}(t)\cdot\underline{\hat{n}}^{(Ka)}*(t)\right\} \end{pmatrix}$$

$$\tag{2}$$

8

of dimension Ka x Ka can be determined for the Ka receiving antennas, taking into consideration the interference power σ^2, which can also be determined from the estimated interference signals. In the case of both the data transmission and digital signal processing at the receiving end, discrete-time samples are available as signals which can be subdivided into finite blocks due to their burst structure. If the subscriber signals are detected burst by burst, it is sufficient to determine information about the interference burst by burst. Accordingly, the interference signals at the individual antennas,

estimated in accordance with the embodiments of the method according to one aspect of the invetion, can be represented as vectors

$$\underline{\hat{n}}^{(ka)} = \left(\underline{\hat{n}}_1, \underline{\hat{n}}_2 ... \underline{\hat{n}}_{WB}\right)^T, ka = 1..Ka \tag{3}$$

where $\underline{\hat{n}}_i$, i=1..WB, are the WB samples of the interference signal over one burst, since these interference signals are time-discrete and limited in time. The embodiment of the method according to one aspect thus leads to finite, discrete-time covariance functions.

Paragraph beginning on line 9 of page 5 has been amended as follows:

Instead of forming the expected value when determining the covariance functions, which requires infinite averaging over the estimated samples of the interference, the temporal averaging is preferably finite in real systems. It is performed over a previously defined number Z of bursts. In the case of a mobile radio system, Z depends on the rate of change of the constellation of mobile stations. If the constellation of mobile stations changes greatly from burst to burst, Z must be selected to be equal to one. If not, Z can be greater than 1. If the Z vectors according to (3) at the Ka antennas according to

9

$$\underline{\hat{N}}_t^{(ka)} = \left(\underline{\hat{n}}_1^{Ka}, \underline{\hat{n}}_2^{Ka} ... \underline{\hat{n}}_Z^{Ka}\right)^T, ka = 1..Ka \tag{4}$$

are ordered into in each case WB x Z matrices, estimates

$$\underline{\hat{R}}_n^{(l.m)} = \frac{1}{Z} \cdot \underline{\hat{N}}_t^{(l)} \cdot \underline{\hat{N}}_t^{(m) \cdot T}, \qquad l, m = 1..Ka$$

$$\tag{5}$$

of the temporal covariance matrices can be formed in derivation of (1). The following then holds for the estimate of the total covariance matrices:

Paragraph beginning on line 34 of page 6 has been amended as follows:

An important advantage, which can be achieved with the method according to the invention, lies in

that, instead of possibly faulty information about the interference to be expected, the information about the interference is obtained from the actual received signal and is thus continuously updated. A further advantage lies in the possibility of obtaining information both on the spatial correlation characteristics of the interference and on the temporal correlation characteristics of the interference.

Paragraph beginning on line 5 of page 7 has been amended as follows:

This information can be used either directly to suppress interference when estimating the user signals from the received signals. Alternatively, information about the directions of incidence of the interference at the receiver can be obtained from the information about the spatial correlation characteristics of the interference, depending on the signal processing algorithm. In the case of multi-antenna receivers, the information about the directions of incidence of the interference at the receiver or, respectively, about the spatial correlation characteristics of the interference can be used for generating directional patterns. The patterns,

of which selectively have less gain in those directions from which strong interference signals arrive at the receiver, cause the ratio between useful power and interference power at the receiver end to be maximized.

Paragraph beginning on line 5 of page 7 has been amended as follows:

The previous considerations relate to the receiver end. In duplex systems, each receiver is paired with a transmitter. If multi-antenna systems are used for receiving and transmitting, the information about the received interference (obtained in accordance with the method explained above) can be used for advantageously driving the antennas in the transmitting case. The basic idea of this is that sending one's own signals into the directions from which strong interference signals are incident tends to produce strong interference in other receivers. When a number of antennas is used, therefore, the knowledge of the main directions of interference at the receiver end can be generally used, independently of the transmission system considered, to radiate as little power of the transmitted signal as possible in the directions of the main interference source and thus to reduce interference seen throughout the system.

Paragraph beginning on line 11 of page 8 has been amended as follows:

The transmitted bursts include two data blocks and a midamble arranged between them which provides for the channel estimate at the receiver end. In the text which follows, the first data block of a burst will be considered in the description of the data detection. A corresponding observation would apply to the second data block. According to R. Schmalenberger, J.J. Blanz: Multi antenna C/I balancing in the downlink of digital cellular mobile radio systems. Proc. IEEE Vehicular Technology Conference (VTC'97), Phoenix, 1997, p. 607 to 611, a system matrix A can be set up which includes both the K * Ka channel impulse responses of the K subscribers to the Ka receiving antennas and the type of signal generation at the transmitter end. Together with the total data vector d, which includes the data blocks of the K subscribers, and a total interference vector n, the total received-signal vector e

11

$$e = Ad + n \qquad\qquad\qquad (12)$$

is obtained. e includes samples of the received signals at all Ka antennas which are based

on the first data block of a transmitted burst. Firstly, a channel estimator 1 forms a channel

estimate and a common detector 2 performs joint detection of the subscriber signals R.

Schmalenberger, J.J. Blanz: Multi antenna C/I balancing in the downlink of digital cellular

mobile radio systems. Proc. IEEE Vehicular Technology Conference (VTC'97), Phoenix, 1997,

p. 607 to 611, by the generally disturbed received signals e. In TD-CDMA systems, algorithms

which can include the knowledge of the entire covariance matrix according to (8) are used for the

joint data estimate of subscribers.

Paragraph beginning on line 1 of page 9 has been amended as follows:

One example of such algorithms is the zero-forcing algorithm. In one- or multi-antenna

receivers in systems according to the prior art, it is assumed that the temporal covariance matrix

R_t can be determined directly from the spectral shape of the transmitted signals. In the text which

follows, this covariance matrix is designated by R_t. This matrix R_t is taken into consideration in

the data detection, even though the actual temporal correlations of the interference signals at the

receiving site may deviate from the assumed temporal correlations due to multi-path propagation

of the interference from an interference source.

Paragraph beginning on line 14 of page 9 has been amended as follows:

In the case of multi-antenna receivers in systems according to the prior art, the spatial

correlations of the interference are not taken into consideration in the detection of the data and/or

in the channel estimate, i.e. the covariance matrix R_s is replaced by the Ka x Ka unity matrix

$I^{(Ka)}$. Thus, there is no optimum data detection in the sense of the zero-forcing algorithm in

systems according to the prior art. The method according to the invention can be used for

improving the data estimate and the channel estimate by prior estimating of the covariance

matrix R_n of the interference due to the estimating of the received interference at each antenna,

as shown in figure 1.

Paragraph beginning on line 27 of page 9 has been amended as follows:

To estimate the interference, a conventional data detection is first performed for a number

of received bursts, using the matrix

$$\underline{R}_n = I^{(Ka)} \otimes \underline{\tilde{R}}_t \tag{13}$$

for the covariance matrix R_n according to (8), using the matrix $\underline{\tilde{R}}_t$. This provides an

estimate

$$\underline{\hat{d}} = \left(\underline{\hat{A}}^{*T} R_n^{-1} \underline{\hat{A}} \right)^{-1} \underline{\hat{A}}^{*T} R_n^{-1} \underline{e} \tag{14}$$

of the transmitted data which can be used for the approximate reconstruction of the received

signal based on the user signals

$$\underline{\hat{e}}_d = \underline{\hat{A}} \cdot \underline{\hat{d}} \tag{15}$$

by the system matrix $\underline{\hat{A}}$ which includes the information about the estimated K * Ka

channel impulse responses. The reconstruction $\underline{\hat{e}}_d$ is performed in a signal reconstructor 5. Units

3 and 4 (FEC decoder and FEC coder) can be arranged between units 2 and 5. Unit 3 performs

FEC decoding at the receiver end for the case in which FEC coding is taken into consideration in

the signal processing at the transmitter end. In unit 4, a corresponding FEC coding of the

estimated data takes place to obtain correct signal reconstruction. Subtracting the reconstructed

received signal $\underline{\hat{e}}_d$ according to (15) from the actual received signal e according to (12) makes it

possible to determine an estimate

$$\hat{\underline{n}} = \underline{e} \cdot \hat{\underline{e}}_d \qquad\qquad\qquad (16)$$

for the total interference factor n according to (7). From the estimates of the interference signals at the individual antennas, which were thus obtained, both the spatial correlation characteristics of the interference, see (11), and the temporal correlation characteristics of the interference, see (5), and thus the covariance matrix $\hat{\underline{R}}_n$ of the interference according to (6) can be estimated in an estimating unit 6.

Paragraph beginning on line 32 of page 10 has been amended as follows:

Taking into consideration the estimated covariance matrix, the signals received at the individual antennas can be subjected both to an improved channel estimate, if such a one is required, and to an improved data estimate R_n according to (13) being replaced by $\hat{\underline{R}}_n$.

Paragraph beginning on line 1 of page 11 has been amended as follows:

The procedure described up to here can be iteratively continued. Assuming that the interference scenario, and thus also the correlation characteristics of the interference, do not or do not significantly change during the provided period of estimating the matrix and in the subsequent period which is provided for estimating new data, the estimated covariance matrix $\hat{\underline{R}}_n$ can be used for estimating new data in order to achieve an improvement in the data estimate.

Please delete lines 1-22 on page 12.

On page 13, line 1, please replace "Patent Claims" with --WHAT IS CLAIMED IS--.